Coordination Compounds

GENERAL INTRODUCTION:

Transition metals form a large number of complex compounds which are known as coordination compounds. Formation of coordination compounds, however, is not restricted to transition metals but is also exhibited by certain other metals though to a limited extent. For example, chlorophyll is a coordination compound of magnesium. Coordination compounds are used in metallurgical operations, as industrial catalysts, in textile dyeing, and electroplating and in medicinal chemistry.

Double Salts and Complex Compounds:

When solutions of two or more salts are mixed in their simple molecular (stoichiometric) proportion and then evaporated, crystals of new compounds separate out. These new compounds are called addition or molecular compounds.

(i) **Double salts**: Those compounds which lose their identity in solution and break down into simple ions are called double salts. These exist in crystalline state. For example, an aqueous solution of potash alum $[K_2SO_4.Al_2(SO_4)_3.24H_2O]$ gives the test for K^+, Al^{3+} and SO_4^{2-} ions in solution form.

(ii) **Complex Compounds:** Molecular or addition compounds (obtained by evaporating the solution of two compounds in molar proportions) which retain their identities even when dissolved in water or any other solvent and having properties completely different from those of the constituents are called complex or coordination compounds.

Types of Complexes:

The complexes can be divided into three different categories as follows………

(i) **Cationic complexes**: These are the complexes in which the complex ion carries a net positive charge. For example, $[Cr(NH_3)_6]^{3+}$

(ii) **Anionic complexes**: These are the complexes in which the complex ion carries a net negative charge. For example, $[Fe(CN)_6]^{4-}$, $[Fe(CN)_6]^{3-}$ $[Ag(CN)_2]^-$ etc

(iii) **Neutral or molecular complexes**: These are the complexes which do not yield oppositely charged ions in solution. For example, $[Ni(CO)_4]$, $[Co.Cl_3(NH_3)_3]$ etc.

Perfect or penetrating complexes: Complexes such as $K_4[Fe(CN)_6]$, $Na_3[Co(NH_3)_6]$ etc in which the complex ion is quite stable and almost undissociated in solution are called perfect or penetrating complexes.

Imperfect or normal complexes: Complexes such as $K_2[Cd(CN)_4]$ in which the complex ion is not stable and dissociates to an appreciable extent are called imperfect or normal complexes.

DISTINCTION BETWEEN DOUBLE SALTS AND COMPLEX COMPOUNDS

Double Salts	Complex Compounds
These exist only in crystal lattices but breakdown into their constituents when	These exist in the solid state as well as in the solution form because even in the solution, the

dissolved in water or any other solvent	complex ion does not dissociate into ions
These usually contain two simple salts in equimolar proportions	The constituent salts from which they are formed may or may not be in equimolar proportions.
Components of a double salt do not lose their identity on the formation of a double salt. Hence, properties of a double salt are essentially the same as those of the constituent compounds.	Components of a complex ion lose their identity on the formation of a complex. Hence, properties of a complex compound are entirely different from the constituent salts.
In a double salt, metal ions exhibit their normal valency	In a complex compound, the metal ion exhibits two types of valencies called primary and secondary valencies
Double salts are ionic compounds and do not have any coordinate bond	Complex compound may or may not be ionic. However, the complex part of the compound always contains coordinate bond
Double salts lose their identity in solution.	Coordination (complex) compounds retain their identity in solution.

***Important terms used in Coordination Compounds*:**

(i) **Coordination entity (complex):** A coordination entity or complex may be defined as an electrically charged ion or a neutral molecule which is formed by the combination of a central atom or ion usually of a metal with one or more neutral or one or more other simple ions or in some cases positive groups also.

(ii) **Central ion and ligand**: The neutral metal atom or cation to which one or more neutral molecules or anions are attached with the help of coordinate bonds is called the central ion while the molecules or ions thus, attached are called ligands.

Types of Ligands (Denticity of Ligands):

The number of coordination sites or donor groups in a ligand is called its denticity.

The ligands are classified depending upon the number of coordination sites in it and accordingly it may be termed as unidentate, didentate or bidentate, tridentate…………polydentate depending upon 1,2,3 or more coordination sites in it.

(I) **Unidentate/Monodentate ligands**: If a ligand contains one donor atom or coordination site, it is called unidentate ligand.

(II) **Polydentate/Multidentate ligands**: When a ligand has two or more donor atoms which may simultaneously coordinate to metal atom, the ligand is known as polydentate ligand.

Depending upon the number of donor sites, these ligands may be termed as didentate (two donor atoms), tridentate (three donor atoms), tetradentate (four donor atoms), pentadentate (five donor atoms) and hexadentate (six donor atoms).

Symmetrical and Unsymmetrical didentate ligands:

Such didentate ligands in which the two coordinating groups are same are called symmetrical didentate ligands, for example ethane 1,2-diamine. Such didentate ligands in which two coordinating groups are different are called unsymmetrical didentate ligands. For example glycinato ion

1. **Chelating ligand**: It is a multidentate ligand which coordinates with central metal atom to form a ring compound. The process is called chelation. The compounds formed are called chelate compounds. For example, $[Cu(en)_2]^{2+}$ is called a chelate and en (ethane 1,2-diamine) is a chelating ligand because it forms a ring structure with Cu^{2+}.
2. **Ambidentate ligands**: These are the ligands which have two or more different donor sites but only one of these is attached to a single metal atom at a given time. For example, thiocyanato (SCN^-) and isothiocyanato (NCS^-).
3. **Bridging ligand**: A bridging ligand is one that can simultaneously bind itself to more than one metal ion. OH^-, Cl^-, NH_2^- etc can act both as monodentate and bridging ligands.

(iii) **Coordination number**: The ligands are attached to the central metal or ion through coordinate bonds. The total number of coordinate bonds made by all the ligands with the metal is called coordination number of the metal atom or its ion.

(iv) **Coordination sphere**: The central ion and the ligands which are directly attached to it are enclosed in square brackets and are collectively termed as the coordination sphere.

(v) **Coordination Polyhedron**: The spatial arrangement of the ligand atom which are directly attached to central atom/ion is called coordination polyhedron about the central atom.

(vi) **Homoleptic Complexes**: Complexes in which the central atom/ion is bound to only one type of ligands are known as homoleptic.

(vii) **Heteroleptic complexes**: Complexes in which the central atom/ion is bound to more than one type of ligands are known as heteroleptic.

(viii) **Homonuclear Complexes**: Complexes in which only one metal atom is present are known as Homonuclear complexes. For example $[Co(NH_3)_6]^{3+}$

(ix) **Polynuclear complexes**: Complexes in which more than one metal atom is present are known as polynuclear complexes.

OXIDATION NUMBER (OR STATE)

It is an electric charge which the central metal has or appears to have when bonded to other ligands.

Determination of oxidation number: In order to find oxidation number (O.N) of the central metal atom, proceed as follows……

(i) The O.N of neutral ligands like H_2O, NH_3, ethylene-diamine (en), pyridine (py), NO, CO etc = zero
(ii) The O.N of negative ligands = charge on the ligand, e.g, the O.N of Cl^-, CN^- = -1 each
(iii) The O.N of cation = charge on the cation, e.g, the O.N of K^+ = +1

Q. Find the O.N of Fe in $K_4Fe(CN)_6$?

Solution: 4 x O.N of K + O.N of Fe + 6 x O.N of CN^- = 0

Or 4 x (+1) + O.N of Fe + 6 x (-1) = 0

Or O.N of Fe = 6-4 = +2

Q. Find the O.N of Pt in $[Pt(en)(H_2O)_2(NO_2)(Cl)]^{2+}$?

Solution: O.N of Pt = +2 – (O.N of en + 2 x O.N of H_2O + O.N of NO_2 + O.N of Cl)

Or O.N of Pt = +2 – [0 + 2 x 0 + (-1) + (-1)] = +2 + 2 = +4

Naming of Coordination Compounds:

The rules recommended by IUPAC for naming coordination compounds are as follows

(i) Order of naming ions
(ii) Naming of coordination entity
(iii) Naming of ligands
(iv) Order of naming ligands
(v) Use of numerical prefixes
(vi) Naming of central metal ion
(vii) Naming of geometrical isomers
(viii) Naming of optical isomers

ISOMERISM IN INORGANMIC COMPLEXES:

Types of isomerism

As in case of organic compounds, the coordination compounds show two main types of isomerism

(A) Structural isomerism and (B) Stereoisomerism or space isomerism.

(A) **Structural isomerism**: This type of isomerism arises due to the difference in structures of coordination compounds. It may further be subdivided into different types as follows.

(i) ***Ionization isomerism***: This type of isomerism is shown by such compounds in which the counter ion is itself a potential ligand and can displace a ligand which then can become the counter ion. In such isomers, the position of groups within or outside the coordination sphere differs.

Example: (a) $[Co(NH_3)_5SO_4]Br$ liberates Br^- in solution and is red and gives pale yellow precipitate with $AgNO_3$ due to the formation of AgBr and $[Co(NH_3)_5Br]SO_4$ liberates SO_4^{2-} in solution and is purple and gives white precipitate with $BaCl_2$ solution.

(b) $[Pt(NH_3)_3NO_2]Br$ liberates Br^- in solution and $[Pt(NH_3)_3Br]NO_2$ liberates NO_2^- in solution

(c) $[Co(NH_3)_5(NO_3)]SO_4$ gives white ppt with $BaCl_2$ solution and $[Co(NH_3)_5(SO_4)]NO_3$ does not give any white precipitate with $BaCl_2$ solution.

(d) $[Pt(NH_3)_4 Cl_2]Br_2$ forms pale yellow ppt with $AgNO_3$ solution and $[Pt(NH_3)_4Br_2]Cl_2$ gives white ppt with $AgNO_3$ solution.

(ii) ***Linkage Isomerism****:* This type of isomerism is shown by such complexes which contain a monodentate ligand (ambidentate) having more than one donor atom. Theoretically, the main requirement is that two different atoms of the same ligand contain an unshared electron pair.

(ii) Coordination Isomerism: This type of isomerism is shown by such compounds which contain both cationic and anionic species and it results from the interchange of ligands between the two complex ions. For example, [Co(NH3)6] [Cr(CN)6] and [Cr(NH3)6] [Co(CN)6]; [Co(NH3)6] [Cr(C2O4)3] and [Cr(NH3)6] [Co(C2O4)3]; [Co(C2O4)2(en)] [Cr(C2O4) (en)2] and [Co(C2O4)3] [Cr(en)3], [Cu(NH3)4] [PtCl4] and [Pt(NH3)4] [CuCl4]

This isomerism is also shown by such compounds which contain same metal ion in cationic and anionic species, for example, [Cr(NH3)6] [Cr(NCS)6] and [Cr(NH3)4(NCS)2] [Cr(NH3)2(NCS)4]

(iii) Solvate Isomerism: This is a special kind of ionization isomerism which arises on account of solvent molecules to appear in variety of ways, inside and outside the coordination sphere

to give a number of solvate isomers. This type of isomerism is called hydrate isomerism if the solvent is water. Three isomers of CrCl3.6H2O are known

From the conductivity measurement and quantitative precipitation of the ionized chjlorine, they are assigned the following formulae

[Cr(H2O)6]Cl3	Violet	Three ionic chlorines
[CrCl(H2O)5]Cl2.H2O	Pale green	Two ionic chlorines
[CrCl2(H2O)4]Cl.2H2O	Dark green	One ionic chlorine

STEREOISOMERISM OR SPACE ISOMERISM:

When the same molecular formula represents two or more compounds which differ in spatial arrangements of atoms or groups, then such compounds are called stereoisomers. The phenomenon is known as Stereoisomerism (Stereo means occupying space).

The stereoisomerism is further classified into two types

1. Geometrical isomerism (or Cis-Trans Isomerism) and 2 Optical Isomerism (or Mirror image Isomerism)

Geometrical Isomerism: (A) In Cis-isomers, two identical ligands (more specifically donor atoms) occupy the positions adjacent to each other and (B) In Trans-isomers; the two identical ligands occupy the position diagonal to each other.

Square Planar Complexes:

Square planar complexes of the type MA_2X_2, MA_2XY, $MABX_2$ and MABXY can exist as geometrical isomers (here A and B are neutral ligands such as H_2O, NH_3, C_2H_5N, NO, CO etc. whereas X and Y are anionic ligands such as Cl-, CN-, SCN-, NO_2 etc)

Let us consider some examples of geometrical isomerism in square planar complexes:

1. **MA_2X_2 type:**

(a) $[Pt(NH_3)_2Cl_2]$ has two isomers; Cis is pale yellow and Trans is dark yellow coloured.

(b) $[PtCl_2(Py)_2]$ has two isomers; Cis and Trans

(c) $[Pd(NH_3)_2Cl_2]$ has two isomers; Cis and Trans

(d) $[Pd(NH_3)_2(NO_2)_2$ has two isomers; Cis and Trans

2. **MA_2XY type:**

(a) $[PtNH_3Cl(Py)_2]$ has two isomers; Cis and Trans

3. **$M(AB)_2$ type** (in which AB represents an unsymmetrical didentate ligand)

For example, $[Pt_9gly)_2]$ where gly = H_2N-CH_2-COO- (glycinato)

4. **MABCD type:** Square planar complexes form three geometrical isomers. Their structures may be obtained by fixing the position of one ligand.

5. **Bridged binuclear complexes of the type $M_2A_2X_4$**

For example, [PtCl2P(C2H5)3]2

Octahedral Complexes (Coordination number 6):

Geometrical isomerism is shown by octahedral complexes of the type MA4X2, MA2X4, MA4XY and MA3B3. It may be noted that in octahedral complexes, positions 1-6, 2-4 and 3-5 are trans while the others such as 1-2, 1-3, 2-3, 6-4, 4-5, and 1-5 are cis to each other.

1. **MA_4X_2 or MA_2X_4 type**: $[Co(NH_3)_4Cl_2]+$, $[Fe(NH_3)_2(CN)_4]-$, $[Cr(NH_3)_4Cl_2]+$, $[Cr(CN)_4Cl_2]^{3-}$; all the compounds have cis and trans isomers.
2. MA_3B_3 type: $[RhCl_3(Py)_3]$, $[Co(NH_3)_3\ (NO_2)_3]$, $[Co(NH_3)_3Cl_3]$, $[Co(H_2))_3\ (NO_2)_3$; all the compounds have cis and trans isomers.
3. **$M(AA)_2X_2$ and $M(AA)_2XY$ type**: $[CoCl_2(en)_2]+$, $[CoClNH_3(en)_2]$
4. **$M(AB)_3$ type**: $[Cr(gly)_3]$ exists in cis- and trans –forms.
5. **$MAAB_2C_2$ type**: $[Co(NH_3)_2enCl_2]^+$ has four geometric isomers
6. **MABCDEF type**: $[Pt(Br)(Cl)I(NO_2)(py)(NH_3)$

NB: Octahedral complexes of the type MA6 and MA5B would not show geometrical isomerism.

CHAPTER AT A GLANCE

1. Double salts are the compounds which lose their identity in solution and break down into simple ions.
2. Molecular or addition compounds which retain their identities even when dissolved in water or any other solvent and having properties different from those of the constituents are called complex or coordination compounds.
3. The branch of chemistry which deals with study of coordination compounds is known as coordination chemistry.
4. Cationic complexes are the complexes in which the complex ion carries a net positive charge.
5. Anionic complexes are the complexes in which the complex ion carries a net negative charge.
6. Neutral or molecular complexes are the complexes which do not yield oppositely charged ions in solution.
7. Complexes in which complex ion is quite stable and almost undissociated in solution are called perfect or penetrating complexes.
8. Complexes in which the complex ion is not stable and dissociates to an appreciable extent are called imperfect or normal complexes.
9. Coordination entity or complex is an electrically charged ion or a neutral molecule which is formed by the combination of central atom/ion usually of a metal with one or more neutral molecules or on or more simple ions or in some cases positive group also.
10. Central atom/ion is the neutral metal atom or cation to which one or more neutral molecules or anions are attached with the help of coordinate bond.
11. The molecules or ions attached to the central ion with the help of coordinate bonds are called ligands.
12. The number of coordination sites or donor groups in a ligand is called the denticity of the ligand.
13. A ligand containing one donor tom or coordination site is called unidentate ligand.
14. A ligand is known as the polydentate ligand if it has two or more donor atoms which may simultaneously coordinate to metal.
15. A chelating ligand is a multidentate ligand which coordinates with central metal atom to form a ring compound.
16. Ambidentate ligands are the ligands which have two or more different donor sites but only one of these is attached to a single metal atom at a given time.
17. A ligand which can bind itself to more than one metal atom/ion is called a bridging ligand.
18. The total number of coordinate bonds made by all the ligands with the metal is called the coordination number of the metal or its ion.

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19. Complexes in which the central atom/ion is bound to only one type of ligands are known as homoleptic.
20. Complexes in which the central atom/ion is bound to more than one type of ligands are known as heteroleptic.
21. Complexes in which more than one metal atom I present are known as polynuclear complexes.
22. Oxidation number is the charge which the central metal has or appears to have when bonded to ligands.
23. Complex ion is always represented in square bracket.
24. Werner is known as the father of coordination chemistry.
25. In complex compounds, the transition metal can act as Lewis acid and the ligand as Lewis base.
26. Transition metals can form complexes both in the zero, positive and low negative oxidation state.
27. Total sum of the electrons of the central metal atom (or ion) and accepted electrons from the ligands after complex formation is known as effective atomic number (EAN). According to Sidgwick, complex I stable if EAN is equal to the atomic number of the nearest noble gas, e. g., $F_2(CO)_5$, the EAN is equal to 26 + 2 x 5 = 36 which is the atomic number of nearest noble gas krypton.
28. Compounds having same molecular formula but different chemical or physical properties are known as isomers and the phenomenon is known as isomerism.
29. Ionization isomerism is shown by such compounds in which the counter ion is itself a potential ligand and can displace a ligand which then can become the counter ion.
30. Linkage isomerism is shown by such complexes which contain a monodentate ligand having more than one donor atom.
31. Coordination isomerism is shown by such compounds which contain both cationic and anionic species and it results from the interchange of ligands between the two complex ions.
32. Solvate isomerism is a special type of ionization isomerism which arises on account of solvent molecules to appear in a variety of ways, inside and outside the coordination sphere.
33. Two or more compounds having the same molecular formula but which differ in the spatial arrangement of atoms or groups are called stereoisomer and the phenomenon is called stereoisomerism.
34. Compounds having same empirical formula but different molecular formula are called polymerization isomers and the phenomenon is called polymerization isomerism. However, this is not a true type of isomerism.
35. Optical isomerism is not possible in case of square planner complexes.
36. Geometrical isomerism is not possible in tetrahedral complexes and square planner complexes of the type MA_4, MAB_3 and MA_3B where A, B, C are ligand.

37. Octahedral complexes of the type [M(ABCDEF)] have fifteen different geometrical isomers with a pair of enantiomers. However, no enantiomer has been resolved.

38. Polydentate ligands are said to have flexidentate character if they o not use all their donor atoms to form coordinate bonds with metal atom ion. For example, EDTA, a hexadentate ligand can also behave as pentadentate and tetrantate ligand.

39. The stability of a complex depends upon (i) charge on the central metal ion, (ii) basicity of the ligands. In general, more is the charge on the central metal atom; greater is the stability of a complex. On the other hand, the ligand with greater basicity forms a more stable complex.

40. Chelates with five membered rings are very stable if the ligands do not contain double bonds, e. g., ethylenediamine. However, chelates with six membered rings are very stable if the ligands contain double bond, e. g., acac.

41. The greater thermodynamic stability of a complex with a cyclic polydentate ligand in comparison to a complex formed with a non-cyclic ligand is known as macrocyclic effect.

42. Geometry and magnetic behaviour of a complex ion depends upon coordination number of the central metal atom (or ion) and the nature of the ligand.

43. The complex in which the outer d-orbitals (n) d-orbitals are used in hybridization is known as outer-orbital or high spin or hypoligated complex.

44. When inner d-orbital i.e., (n-1) d-orbitals are used in hybridization, the complex is called an inner orbital or spin paired or low spin or hyperligated complex.

45. Hexafluorocobaltate (III) is outer –orbital or high spin or hypoligated complex. The complex hexafluoroferrate (III) also belongs to this category of complexes.

46. Hexaaminecobalt (III) ion is an example of inner d-orbital complex involving d^2sp^3 hybridization. It is a diamagnetic complex.

47. Ligands like CO which are capable of accepting an appreciable amount of □-electron density from the metal atom into empty □ or □ * orbital of their own are called □-acceptor or □-acid ligands.

48. The decrease in energy due to preferential occupation of stable orbitals is called crystal field stabilization energy (CFSE).

49. Prussian blue and Turnbull's blue is pot. Ferric ferrocyanide. However, colour of Turnbull's blue is less intense than Prussian blue. Decrease in colour is due to presence in it of a white compound of the formula $K_2[Fe(Fe(CN)_6]$ named as potassium ferrous ferrocyanide.

50. Wilkinson's catalyst $(Ph_3P)_3RhCl$ is used as a homogeneous catalyst for the hydrogenation of alkene.

51. Ziegler-Natta catalyst (a solution of TiCl4 containing triethyl aluminium) is used as a heterogeneous catalyst in the polymerization of alkenes.

52. Zeise's salt is $[PtCl_3(C_2H_4)]^-K^+$.

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SOME IMPORTANT POINTS TO BE NOTED:

1. Give an example of a double salt.

Ans: Mohr's salt, $FeSO_4.(NH_4)_2SO_4.6H_2O$

2. Give two examples of neutral didentate ligands.

Ans: $H_2NH_2C\text{-}CH_2NH_2$ and bipyridyl.

3. Give one example of positive ligand.

Ans: Nitrosonium ion, NO^+.

4. Give one example of hexadentate ligand.

Ans: EDTA

5. How many moles of AgCl will be precipitated when an excess of $AgNO_3$ is added to a molar solution of $[CrCl(H_2O)_5]Cl_2$?

Ans: Two moles.

6. What is the coordination number of central metal ion in $[Fe(C_2O_4)_3]^{3-}$

Ans: Six

7. What is the oxidation state of Ni in Ni(CO)4

Ans: Zero

8. Write IUPAC name of $K_3[Fe(CN)_6]$

Ans: potassium hexacyanidoferrate (III).

9 Write IUPAC name of $K_3[Fe(CN)_5NO]$

Ans: Potassium pentacyanidonitrosylferrate.

10 Write the name of $[Co(NH_3)_4(H_2O)_2]Cl_3$

Ans: Tetraaminediaquacobalt (III) chloride.

11. Write IUPAC name of $K_2[PdCl_4]$

Ans: Potassium tetrachloridopalladate

12. Write the formula of pentaaminechloridoplatinum (IV) chloride

Ans: $[Pt(NH_3)_5Cl]Cl_3$

13. Write the formula of tetraaminedichloridochromium (III) chloride

Ans: $[Cr(NH_3)_4Cl_2]Cl$

14. Write IUPAC name of $[Co(NH_3)_5ONO]Cl_2$

Ans: Pentaaminenitrito-O-cobalt (III) chloride

15. Write IUPAC name of the complex: $[Cr(H_2O)_5Cl]Cl_2$

Ans: Pentaquachloridochromium (III) chloride

16. Write IUPAC name of the complex: $Na_3[Cr(OH)_2F_4]$

Ans: Sodium tetrafluoridodihydroxochromate

17. Write the IUPAC name of the complex: $[Co_3(NH_3)_5SCN]Cl$

Ans: Pentaaminethiocyanatocabalt (III) chloride.

18. Give the IUPAC name of $(NH_4)_3[Co(ONO)_6]$

Ans: Ammonium hexanitrito-O-cobaltate (III).

19. Write the IUPAC name of $[Ni(H_2O)_6](ClO_4)_2$

Ans: Hexaquanickel (II) chlorate

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20. Name the isomerism shown by $[Cr(H_2O)_5(NCS)]^{2+}$

Ans: Linkage isomerism

21. Write the IUPAC name of $Na_3[Co(NO_2)_6]$

Ans: Sodium hexanitro-N-cobaltate (III)

22. Name the ionization isomer of $[Cr(H_2O)_5Br]SO_4$

Ans: $[Cr(H_2O)_5SO_4]Br$-pentaquasulphatochromium (III) bromide

23. What is the coordination number of the metal atom if its geometry is (i) square planar, (ii) octahedral?

Ans: Square planar: 4; Octahedral: 6.

24. What type of isomerism is shown by $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$?

Ans: Ionization isomerism

25. What type of isomerism is shown by $\{Co(NH_3)_5ONO]Cl_2$ and $[Co(NH_3)_5NO_2]Cl_2$?

Ans: Linkage isomerism

26. What type of isomerism is shown by $\{Co(edta)]^{1-}$ and $[Co(en)_3]^{3+}$?

Ans: Both can show optical isomerism.

27. Why does ammonia readily form a complex while ammonium ion does not?

Ans: Ammonium ion does not have either lone pair of electron or vacant orbital, where as ammonia has lone pair of electron on the nitrogen atom.

28. What type of isomerism is shown by $[Co(NH_3)_6]$ $[Cr(CN)_6]$ and $[Cr(NH_3)_6]$ $[Co(CN)_6]$?

Ans: Coordination isomerism.

29. $[Co(NH_3)_5SO_4]Br$ gives yellow precipitate with $AgNO_3$ solution while $[Co(NH_3)_5Br]SO_4$ does not. Why?

Ans: The later does not give any Br^- ion on ionization.

30. What happens when silver sulfide is shaken with NaCN solution?

Ans: Ag_2S dissolves due to formation of complex $Na[Ag(CN)_2]$.

31. Name the metal present in (i) haemoglobin (ii) chlorophyll?

Ans: (i) Iron, (ii) Magnesium.

32. Name the compound used to determine the hardness of water.

Ans: EDTA

33. Write the number of types of valencies present for metals in complexes according to Werner.

Ans: Two, primary valency and secondary valency.

34. What are primary and secondary valencies according to modern concept?

Ans: Primary valency: Oxidation number and (ii) Secondary valency: Coordination number.

35. Name a neutral ligand.

Ans: Water.

36. What is cis-platin?

Ans: Cis-platin stands for cis-dichloridodiam-mineplatinum (II), used to treat cancer.

37. Name the metal in B-12.

Ans: Cobalt

38. Name two factors which influence stability of a complex.

Ans: (i) Nature of the ligand and (ii) nature of the metal atom or ion.

39. What is crystal field splitting energy?

Ans: The energy between two sets- "e_g" and "t_{2g}" of *d*-orbitals in presence of ligands is called crystal filed splitting energy (CFSE).

40. Why does precipitate of AgCl dissolves in ammonia solution?

Ans Due to the formation of $[Ag(NH_3)_2]^+Cl^-$

41. What happens when excess ammonia is added to copper sulfate solution?

Ans: A deep blue coloured complex ion, $[Cu(NH_3)_4]^{2+}$ is formed.

42. What is Nessler's reagent? How is it prepared?

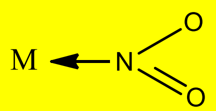
Ans: Alkaline solution of K2HgI4 is called Nessler's reagent.

It is prepared by adding excess of KI to HgCl2 solution

$$4KI + HgCl_2 \longrightarrow K_2[HgI_4] + 2KCl$$

43. Name the type of isomerism when Ambidentate ligands are attached to central metal ion. Give two examples of ambidentate ligands.

Ans: Ambidentate ligands are those which have two different donor atoms leads to linkage isomerism. For example

(i) 

nitro-N

M ← O-N=O

nitro-O

(ii) M ← SCN

thiocyanato

M ← NCS

isothiocyanato

44. What is the most important coordination numbers encountered in coordination compound?

Ans: 4 and 6.

45. How many coordination sites are there in ethylenediamine (NH_2-CH_2-CH_2-NH_2)?

Ans: Two

46. Why does a tetrahedral complex of the type [MA2B2] not show geometrical isomerism?

Ans: This is because the relative position of four ligands remains the same in a tetrahedral complex. Hence, there is no possibility of geometrical isomerism.

47. Write the formula of (i) hexaquairon (II) sulfate, (ii) potassium hexacyanidoferrate (III), (iii) hexamine-platinum (IV) chloride, and (iv) potassium trioxalatoaluminate (III).

Ans: (i) $[Fe(H_2O)_6]SO_4$, (ii) $K_3[Fe(CN)_6]$, (iii) $[Pt(NH_3)_6]Cl_4$, (iv) $K_3[Al(C_2O_4)_3]$

48. Write the IUPAC name of the complex: $Na_3[Cr(OH)_2F_4]$

Ans: Sodium tetrafluoridodihydroxochromate (III)

49. Write the IUPAC name of the complex: $[Co_3(NH_3)_5SCN]Cl$

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Ans: Pentaaminethiocyanatocobalt (III) chloride

50. Only transition elements are known to form carbonyls. Why?

Ans: Transition elements like Ni and Fe form carbonyls in which they show zero oxidation state. This is because of the presence of vacant *d*-orbitals in them.